CONTROL OF POSTHARVEST FUSARIUM TUBER DRY ROT OF WHITE POTATOES

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SUMMARY

Hot-water and hot-chemical treatments controlled postharvest Fusarium tuber dry rot of white potatoes, but not to any greater degree than cold-chemical treatments. Dusts provided some control but were not so effective as sprays or dips. In the laboratory 1,200 ppm of Benlate--methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate and 1,500 ppm Mertect--2(4'-thiazolyl) benzimidazole applied as dips or sprays effectively controlled tuber dry rot consistently. Tests in commercial potato storage showed that Benlate and Mertect controlled tuber dry rot approximately 100 percent when applied at harvest as potatoes were going into storage. No injury was observed with any of the materials used.

Maintaining a constant storage environment of 42° F and 95 percent relative humidity during the storage season reduced tuber dry rot incidence in a commercial storage from 15 percent over the past years to less than 3 percent in the 2-year studies.

INTRODUCTION

Fusarium tuber dry rot, caused by Fusarium roseum (LK) emend. Snyd and Hans. sambucinum, is a serious postharvest disease of white potatoes. Destructive in tubers primarily during storage and transit and in late potatoes, this fungus can cause greater losses than any other disease (3; 4; 8; 11, pp. 16-18; 14. 3/ Susceptibility of tubers to dry rot

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1/ In cooperation with Life Sciences and Agricultural Experiment Station, University of Maine, Orono.

2/ Research Plant Pathologist, Northeastern Region, Agricultural Research Service, USDA, Orono, Maine.

3/ Underscored numbers in parentheses refer to Literature Cited, p. 14.

Thanks are extended to Gerald Flewelling, potato grower, Easton, Maine, for his cooperation and use of his potato storage; also, to the chemical companies who supplied fungicides and other chemicals used throughout this study.

increases as the length of the storage period and storage temperature increases. Infected tubers stored at low temperatures (39° F) showed little rot, but at higher temperatures (60°) the amount of rot increased greatly (1).

Control of tuber dry rot has been attempted by holding tubers at temperatures of 50° to 60° F and high relative humidity (95 percent) for several days after digging, thus providing favorable conditions for the healing of wounds. With the increased mechanization in potato handling and consequent increased wounding, former control methods were not satisfactory. Control by chemicals, therefore, was attempted (3). Organomercury compounds were the first chemicals used and provided various degrees of control (12, 13). Later diphenyl was found to reduce infection under laboratory conditions but proved both ineffective and phytotoxic to tubers in the field (7). Benlate and Mertect gave good control in the laboratory (5). Washing tubers also reduced tuber rot (10).

Since mercury compounds are now barred from use, some presently available fungicides were tested for effectiveness in controlling tuber dry rot. These studies show the effectiveness of certain chemicals, the rate of application necessary for acceptable control, and methods of application. The tests were conducted during the storage seasons of 1970-71 and 1971-72 at the Potato Handling Research Center, Presque Isle, Maine.

MATERIALS AND METHODS

Commercially grown Maine Russet Burbank potatoes were used throughout these tests because the variety is highly susceptible to Fusarium tuber dry rot. Potatoes for laboratory tests were selected at harvest and stored at 45° F and 95 percent relative humidity until used. To insure that all potatoes tested were of the same lot and stored under the same conditions, samples which were placed in the bulk bins at the research storage were taken from these same lots to facilitate comparison of laboratory and bulk bin results. Commercial storage tuber samples were carefully selected to insure absence of wounds.

Fusarium roseum (LK) emend, Snyd. and Hans. *sambucinum* was the test organism used in all tests where tubers were artificially inoculated. The inoculations were made by wounding the tubers either with a vegetable grater or banging them on the corner of a box to produce a shatter bruise (type most often found in commercial storage) and dipping the wounded area into a 50,000 spore/ml suspension. Chemical treatments were then applied as dips, sprays, or dusts.

Hot-Chemical and Hot-Water Treatments

Potato tubers were inoculated and held 24 hours at 40° F before treating. Treatments were made by submerging tubers into constant temperature baths containing water or chemical suspensions at 70° or 130° for 2 minutes. The chemicals were applied at the rate of 2 pounds of formulated material per 100 gallons of water. The treatments included were dry check, water, Benlate, Bravo, Dithane M-45, Mertect and Polyram. 4/ After treating, the tubers were allowed to dry for 2 hours before placing 5 tubers in each of 5 paper sacks (total 25 tubers per treatment) and storing for 120 days before scoring for tuber dry-rot development.

Fungicide Screening Tests

Three screening tests were conducted to determine effectiveness of various chemicals on control of tuber dry rot. Previous tests (7) showed that some of the chemicals used provided fairly good control but required further testing. The other chemicals used either controlled *Fusarium* on some other crop or were untested against *Fusarium*.

In all screening tests, tubers were inoculated, treated, and stored for 15 or 60 days at 55° F and 95 percent relative humidity before scoring for tuber dry rot development.

In the first test the treatments were check, Benlate, Busan 72, Dithane M-45, Dowicide A, Mertect, and TCMTB. Dithane M-45, Mertect and TCMTB were applied as dusts at 1 pound per cwt and Benlate, Busan 72, Dowicide A and Mertect were applied as dips at 2-pounds' formulated material per 100 gallons.

The second test contained only those materials which had shown control in previous testing when applied as dusts or dips. The treatments were check, Benlate, Bravo, Dithane M-45, Mertect and Polyram, all applied as sprays at the 2 pounds formulated material per 100 gallon rate using a Microsol Fog Generator (6).

In the third test six new materials, Fusarex, HTH, HPMTS:TCMTB, Mertect flowable, TCMTB, and Mertect WP and Benlate were included. Fusarex was applied as a dust at 1 pound per 6 cwt and HPMTS:TCMTB at 1 pound per cwt. All other materials were applied at 1,500 ppm as a spray.

4/ See appendix, table 7 for chemical identification of materials used.

Application Rates

This test was designed to determine the most effective and economical rates of Benlate and Mertect required to control tuber dry rot. Since Mertect was available in two formulations, flowable and wettable powder, both were included. Tubers were inoculated, treated with either Benlate or Mertect at 0, 250, 500, 1,000, or 2,000 ppm, and stored for 60 days at 55° F and 95 percent relative humidity before scoring for tuber dry-rot development.

Commercial Storage Studies

Studies were conducted for two storage seasons (1970-72) in a commercial potato storage to confirm laboratory results of chemical application for tuber dry-rot control and to study the effects of storage environment on the amount and development of rot in storage. The storage was a typical inground, 15,000-barrel Maine storage with a history of high Fusarium tuber dry rot in Russet Burbank processing stock.

Chemical Application

Samples of Russet Burbank tubers were randomly selected as the storage was being filled and prepared for testing. Each treatment consisted of four samples containing 50 tubers.

In the first year's study (1970-71) there were four treatments: Unwounded check, wounded check, wounded + Polyram, and wounded + Dithane M-45. The second year (1971-72), Mertect and Benlate treatments were added. Polyram and Dithane M-45 were applied as dusts at 1 pound per cwt while Mertect and Benlate were applied as 20-second dips at 2 pounds' formulated material per 100 gallons. Wounding was accomplished by striking the tuber on a wooden beam, thus providing a wound similar to that received during the storage operation through which natural infection could occur. The unwounded check was included to aid in studying the effect of the storage environment on disease development. After treating, the samples were randomly placed throughout a storage bin as it was filled with potatoes. In the first year's study the samples were removed at the end of 4 months' storage and scored for dry-rot development. In the second years' study, the storage period was increased to 5.5 months.

Storage Environment

The studies on storage environment were conducted for 2 years in the same commercial storage as the chemical studies. Hygrothermographs placed at two locations, one at floor level and the other 15 feet above floor level, monitored temperature and relative humidity. The owner of the storage used in this study previously had been unable to maintain the storage environment at the recommended 40° F and 95 percent relative humidity. Excess moisture dripped from the ceiling making ventilating a necessity by exhausting the moist air and bringing in dry air to help absorb the excess moisture, a practice that enhances the development of tuber dry rot. A strict storage management program was devised. This program involved closing all vents to prevent moisture loss and installing three fans to circulate the air and prevent moisture buildup on the ceiling. The air circulation was combined with shell ventilation to maintain a constant temperature throughout the storage.

RESULTS

Hot-Chemical and Hot-Water Treatments

At the end of 120 days' storage at 55° F and 95 percent relative humidity, 64 percent of the tubers from the dry and cold-water checks developed tuber dry rot (table 1). The hot-water treatment reduced rot development about 44 percent. Hot Dithane M-45 and Polyram suspensions also gave better control than cold suspension treatments, but the reverse was true for the Benlate, Bravo, and Mertect suspension treatments. The hot suspension treatment of Bravo greatly decreased its effectiveness. Mertect gave the best control of the materials tested when applied as a hot or cold suspension. No toxic effect to tubers was observed in any of the treatments.

A later test confirmed that Benlate and Mertect cold suspensions were equal to or better than hot suspensions in the control of tuber rot. Therefore, cold suspensions were used in all later tests.

Fungicide Screening Tests

In the first fungicide screening test, Mertect wettable powder dip, Mertect dust, and Benlate wettable powder dip gave acceptable control of tuber rot (table 2). No other material tested provided adequate control.

In the second test where all treatments were applied by using a Microsol Fog Generator, Mertect again gave the highest degree of control (table 3). Benlate, Bravo and Dithane M-45 gave unacceptable control. Polyram provided no control.

TABLE 1.--Hot-and cold-water chemical treatments to control Fusarium tuber rot 1/

Postharvest treatment	Percentage of diseased tubers 2/
Checks:	
Dry (untreated)	64a
Cold (70° F water)	64a
Hot (130° F water)	28 ef
Benlate 50% wettable powder 3/:	
Cold	20 f
Hot	32 de
Bravo 75% wettable powder:	
Cold	16 g
Hot	40 c
Dithane M-45 80% wettable powder:	
Cold	56 b
Hot	32 de
Mertect 60% wettable powder:	
Cold	8 h
Hot	12 gh
Polyram 80% wettable powder:	
Cold	36 d
Hot	28 ef

1/ Russet Burbank tubers were wounded, inoculated with *Fusarium roseum* cultivar *sambucinum*, treated with hot and cold-water chemical suspensions, and stored for 120 days at 55° F and 95 percent relative humidity, 1970.

2/ Each figure is an average of 5 replicates and is based on a total of 25 tubers. Values followed by a common letter do not differ significantly at the 5-percent level according to Duncan's New Multiple Range Test.

3/ All chemical materials applied at 2 pounds' formulated material per 100 gallons as a 20-second dip.

TABLE 2.--Fusarium tuber dry-rot development in Fusarium inoculated and chemically treated tubers 1/

Treatment	Application rate	Percentage of diseased tubers 2/
Check	None	58.3 b
Benlate 50% wettable powder	2 lb/100 gal	7.4 d
Busan 72% EC	1,500 ppm	29.5 c
Dithane M-45 8% dust	1 lb/cwt	29.1 c
Dowicide A 97%	2 lb/100 gal	31.9 c
Mertect 10% dust	1 lb/cwt	10.0 d
Mertect 60% wettable powder	2 lb/100 gal	5.8 d
TCMTB 6% dust	1 lb/cwt	77.4a

1/ Russet Burbank tubers were wounded, inoculated with *Fusarium roseum* cultivar *sambucinum*, treated with fungicide as dips or dusts, and stored for 75 days at 55° F and 95 percent relative humidity, 1970.

2/ Each figure is an average of 5 replicates and is based on a total of 70 tubers. Values followed by a common letter do not differ significantly at the 5-percent level according to Duncan's New Multiple Range Test.

TABLE 3.--Fusarium tuber dry-rot development in *Fusarium* inoculated and chemically treated tubers 1/

Treatment	Application rate, lb/100 gal	Percentage of diseased tubers 2/
Check	0	68a
Benlate 50% wettable powder	2	40 b
Bravo 75% wettable powder	2	44 b
Dithane M-45 80% wettable powder	2	32 c
Mertect 60% wettable powder	2	12 d
Polyram 80% wettable powder	2	66a

1/ Russet Burbank tubers were wounded, dipped in a *Fusarium roseum* cultivar *sambucinum* spore suspension, and fungicide applied with a Microsol Fog Generator and stored for 60 days at 55° F and 95 percent relative humidity, 1972.

2/ Each figure is an average of 5 replicates and is based on a total of 100 tubers. Values followed by the same letter are not significantly different at the 5-percent level by Duncan's New Multiple Range Test.

In the third test (table 4) of the seven, only three--Benlate, Mertect, and Topsin M--showed any degree of control. Mertect wettable powder gave the highest degree of control followed by Mertect flowable, Topsin M, and Benlate. All other materials were ineffective in controlling tuber dry rot.

Application Rates

Adequate control of tuber dry rot was obtained with 1,000 ppm of Benlate 50 percent wettable powder, Mertect 60 percent wettable powder, and Mertect 42 percent flowable (table 5). Two thousand parts per million of Mertect wettable powder and flowable gave about 50 percent better control than at the 1,000 ppm rate. Benlate gave about equal control at both rates. The flowable formulation of Mertect at 500 ppm gave control equal to Mertect wettable powder and Benlate at 1,000 ppm.

Commercial Storage Studies

Chemical application

In the first year study samples showed that the wounded check had 27.5 percent diseased tubers compared with 11.0 percent and 15.0 percent for Polyram and Dithane M-45 treated potatoes, respectively (table 6). The unwounded check had 2 percent diseased tubers.

In the second year study Dithane M-45 and Polyram reduced the incidence of rot to 22.5 percent and 21.0 percent, respectively, compared with 45 percent in the wounded check (table 6). Benlate and Mertect almost completely controlled the disease. The unwounded check had 1.8 percent rotted tubers, similar to the 2.0 percent the previous year.

Storage environment

The following of the storage environment program produced a near-perfect recommended environment of a constant 40° F and 95 percent relative humidity. The amount of rot was 1.8 and 2.0 percent for the 2 years compared with about 15 percent in years where this environment was not maintained. The addition of three fans, which circulated the air, prevented the condensation of moisture on the ceiling.

TABLE 4.--Fusarium tuber dry rot development in Fusarium inoculated and chemically treated tubers 1/

Treatment	Application rate	Percentage of diseased tubers 2/
Check	0	95.0a
Benlate 50% wettable powder	1,500 ppm	47.5 b
Fusarex 5% dust	1 lb/6 cwt	85.0a
HPMTS:TCMTB 6% dust	1 lb/cwt	95.0a
HTH 70% granules	1,500 ppm	82.5a
Mertect 42% flowable	1,500 ppm	35.0 c
Mertect 60% wettable powder	1,500 ppm	20.0 d
TCMTB 30% EC	1,500 ppm	92.5a
Topsin-M 70% wettable powder	1,500 ppm	47.5 b

1/ Russet Burbank tubers were wounded, dipped in a *Fusarium roseum* cultivar *sambucinum* spore suspension, and fungicide applied with a Microsol Fog Generator and stored for 60 days at 55° F and 95 percent relative humidity, 1972.

2/ Each figure is an average of 5 replicates and is based on a total of 150 tubers. Values followed by a common letter do not differ significantly at the 5-percent level according to Duncan's New Multiple Range Test.

TABLE 5.--Fusarium tuber rot development in *Fusarium* inoculated and chemically treated tubers 1/

Treatment	Application rate, ppm	Percentage of diseased tubers 2/
Check	0	67a
Benlate 50% wettable powder	250	20 bc
Benlate 50% wettable powder	500	27 bc
Benlate 50% wettable powder	1,000	11 cd
Benlate 50% wettable powder	2,000	15 cd
Mertect 42% flowable	250	37 b
Mertect 42% flowable	500	10 cd
Mertect 42% flowable	1,000	12 cd
Mertect 42% flowable	2,000	5 d
Mertect 60% wettable powder	250	26 bc
Mertect 60% wettable powder	500	20 bc
Mertect 60% wettable powder	1,000	11 cd
Mertect 60% wettable powder	2,000	4 d

1/ Russet Burbank tubers were wounded, dipped in a *Fusarium roseum* cultivar *sambucinum* spore suspension, and fungicide applied with a Microsol Fog Generator and stored for 60 days at 55° F and 95 percent relative humidity, 1972.

2/ Each figure is an average of 5 replicates and is based on a total of 100 tubers. Values followed by the same letter are not significantly different at the 5-percent level by Duncan's New Multiple Range Test.

TABLE 6.--Fusarium tuber rot development in commercially stored tubers 1/

Treatment	Percentage of diseased tubers 2/	
	1970-71	1971-72
Check (not wounded)	2.0 c	1.8 c
Check (wounded)	27.5a	45.0a
Benlate 50% wettable powder 3/	----	.5 c
Dithane M-45-8% dust 4/	11.0 b	21.0 b
Mertect 60% wettable powder 3/	----	0 c
Polyram-7% dust 4/	15.0 b	22.5 b

1/ Russet Burbank tubers were wounded, treated, and stored in a commercial storage at 40°-42° F and 85 to 95 percent relative humidity for 120 days in 1970-71 and 165 days in 1971-72.

2/ Each figure is an average of 4 replicates and is based on a total of 200 tubers. Values followed by a common letter do not differ significantly at the 5-percent level according to Duncan's New Multiple Range Test.

3/ Material applied as 2-lb formulated material/100 gal as a 20-second dip.

4/ Material applied at 1 lb/cwt.

DISCUSSION

Of the treatments applied to whole potatoes, only Benlate and Mertect at 1,500 ppm provided satisfactory control of tuber dry rot. Mertect was the most effective of the materials tested. Topsin-M, a new material, appears to merit further testing.

Data from Washington (2) on the control of *Verticillium albo-atrum* showed that liquid treatments were more effective than dusts. Similar results were obtained for Fusarium tuber dry-rot control in this study. Liquid applications (sprays or dips) provided better coverage and easier application with less waste. Their greatest assets were the lack of irritation to eyes and throat often encountered when using dusts. The equipment for applying liquids is much easier to fit into the handling systems than is equipment for dust application.

The storage studies confirmed laboratory results on chemical control. The near-perfect control of tuber dry rot where Benlate and Mertect were applied at harvest was better than results obtained in the laboratory. This suggests that with the application of chemicals at harvest tuber rot would no longer be the number one storage problem.

Maintenance of storage environment at 40° F and 95 percent relative humidity by using circulating fans, greatly reduced the amount of tuber dry rot in this storage as compared with those of previous years when this environment was not maintained. This is accomplished because proper environmental conditions are favorable for wound healing and reducing the amount of moisture loss from the tuber, thus reducing the amount of cracking and openings for the fungus to enter. Maintaining this environment will reduce disease loss in storage, but infection of tubers during packing and shipment may still occur. Therefore, if potatoes have not been treated when they are put into storage, they should be treated as packed to insure disease-free stock (9). This would be especially beneficial for seed shippers since *Fusarium* tuber dry rot is the largest cause of rejection at destination. Retreatment, before shipment of potatoes treated at harvest, could also reduce losses by protecting the tubers at a time when they are highly susceptible to *Fusarium*.

The use of fungicides and proper storage environment management practices for disease control by processors, packers, and repackers who hold potatoes for extended periods would reduce amounts of diseased potatoes, thus increasing the amount of high-quality, salable product.

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APPENDIX

TABLE 7.--Chemical materials tested for fusarium tuber dry rot control

Trade name and common name	Source, chemical names, and percent active ingredient
Benlate (benomyl)	E.I. duPont de Nemours & Company, Inc., Industrial and Biochemical Department, 308 Lancaster Avenue, Wynnewood, Pa. 19096; methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate; 50% WP, and mixed with Attaclay X 250 to form a 10% active dust.
Bravo (chlorothalonil)	Diamond Shamrock Chemical Company, Agricultural Chemicals Division, 300 Union Commerce Building, Cleveland, Ohio 44115; tetrachloroisophthalonitrile; 75% WP.
Busan 72	Buckman Laboratories, Inc., Manufacturing Chemists, Memphis, Tenn. 38108; 2-(thiocyanmethylthio) benzothiazole: 72% EC.
Dowicide A	Dow Chemical Co., Agricultural Dept., P.O. Box 706, Midland, Mich. 48604; Sodium-O-phenylphenate (tetrahydrate); 97%.
Dithane M-45 (mancozeb)	Rohm and Haas Company, Agricultural and Sanitary Chemicals Department, Independence Mall West, Philadelphia, Pa. 19105; coordination product of zinc ion and manganese ethylenebistidthiocarbamate; 80% WP and 8% dust.
Fusarex (tecnazene)	Sterwin Chemicals Inc., 90 Park Avenue New York, N.Y. 10016; 1,2,4,5-tetrachloro-3-nitrobenzene; 6% dust.
HTH	Olin Chemicals, 120 Long Ridge Road, Stamford, Conn. 06904; sodium chlorite; 70% granuals.
HPMTS:TCMTB	Buckman Laboratories, Inc., Manufacturing Chemists, Memphis, Tenn. 38108; 2-hydroxy-propyl methanethiosulfate and 2-(thiocyano-methylthio) benzothiazole; 6:6 dust.

TABLE 7.--Continued

Trade names and common name	Source, chemical names, and percent active ingredient
Mertect (thiabendazole)	Merck Chemical Division, Merck & Co. Inc., Rahway, N.J. 07065; 2-(4'-thiazolyl)-benzimidazole; 60% WP, 42% flowable, and 10% dust.
Polyram (metiram)	Niagara Chemical Division, FMS Corporation, 100 Niagara Street, Middleport, N.Y. 14105; a mixture of 5.2 parts by weight (83.9%) of ammoniates of ethylenebis (dithiobarbamate) zinc with one part by weight (16.1%) ethylenebis-(dithiocarbamic acid), bimolecular and trimilecular cylic anhydro- and disulfides; 80% WP and 7% dust.
TCMTB	Buckman Laboratories Inc., Manufacturing Chemists, Memphis, Tenn. 2-(thiocyanomethylthio) benzothiazole; 6% dust and 30% EC.
Topsin-M (thiophanate methyl)	Penwalt, Agchem-Decco Division 11, Windsor Drive, Oak Brook, Ill. 60521; dimethyl 4,4-Ophenylenebis (3-thioallophanate); 70% WP.

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